"Fundamental Mechanisms, Predictive Modeling, and Novel Aerospace Applications of Plasma Assisted Combustion"

Program Overview

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Columbus, OH

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MURI Team Members

U. S. Institutional co-PIs

- **Walter R. Lempert, Igor V. Adamovich, J. William Rich, Jeffrey Sutton**
  Ohio State University – Program Lead Institution.
- **Yiguang Ju, Richard B. Miles, and Mikhail Shneider**
  Princeton University.
- **Andrei Starikovskii, Alexander Fridman**
  Drexel University.
- **Richard Yetter**
  Pennsylvania State University.
- **Vigor Yang**
  Georgia Institute of Technology

MURI Team Members

International Collaborators

- **Christophe Laux (Ecole Centrale - Paris)**
  Experimental Kinetics , Plasma Enhanced Mixing/Combustion.
- **Boris Potapkin (Moscow State University)**
  Modeling of fundamental processes and mechanism development.
- **Sergey Leonov (Joint Institute of High Temperature, Moscow)**
  Mixing Enhancement
- **Svetlana Starikovskaya (Ecole Politechnique, Paris)**
  Experimental Kinetics, Discharge Physics
- **Nickolay Aleksandrov (Moscow Inst. of Physics and Technology)**
  Modeling of fundamental processes and mechanism development.
- **Aleksander Konnov (Vrijue Universitat Brussels)**
  Modeling of fundamental processes and mechanism development.
- **Fei Q (Univ. of Sci. and Tech, China)**
  Modeling of fundamental processes and mechanism development.

Program Principal Objective and Primary Deliverables

PRINCIPAL OBJECTIVE

"Develop experimentally validated kinetic mechanisms and modeling codes capable of predicting the impact of nonequilibrium plasmas on reactive processes, particularly on ignition, chemical energy release, and flameholding in combustors of flight vehicle engines."

PRIMARY DELIVERABLES

- **Extensive new experimental data sets of non-equilibrium plasma chemical energy conversion kinetics over a wide range of initial temperatures (300 – 1800 K) and pressures (0.1 – 70 bar), in a variety of complementary new test facilities, specifically designed and fabricated for this program.**
- **Detailed non-equilibrium plasma chemical energy conversion kinetic mechanisms, validated over a wide range of conditions, using data from multiple facilities.**
- **Extensive experimental data sets on ignition delay, flameholding and laminar flame speed augmentation by nonequilibrium discharges, including nsec pulsed, DC/RF, and microwave.**
- **High fidelity multi-dimensional plasma combustion modeling codes, validated in a series of model flows, with emphasis on the high subsonic to supersonic flow regimes.**

Principal Thrust Areas

Thrust 1. Experimental studies of nonequilibrium air-fuel plasma kinetics using advanced non-intrusive diagnostics ***(leader: Richard Miles, Princeton).***

Thrust 2. Kinetic model development and validation ***(leader: Richard Yetter, Penn State):***

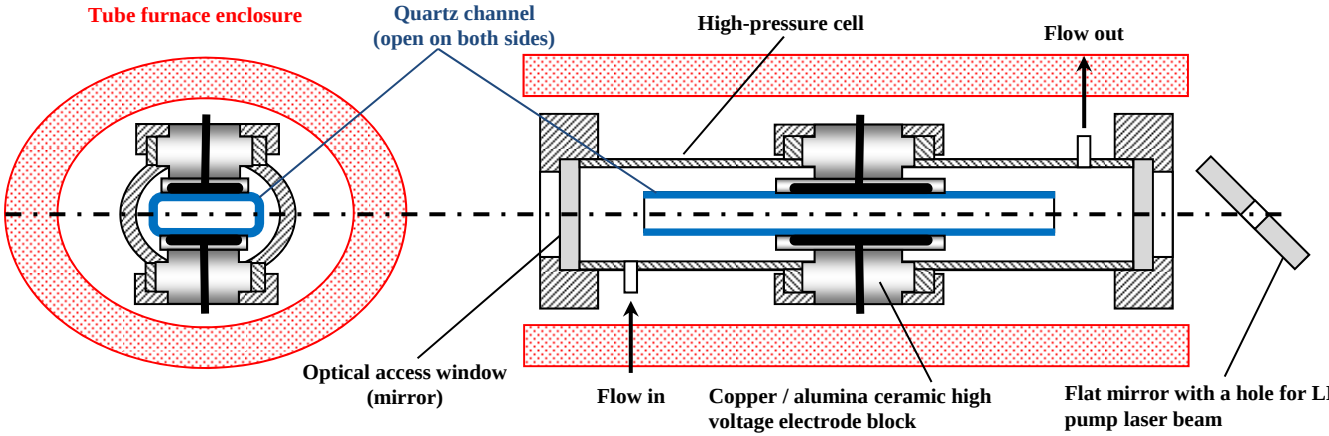
Thrust 3. Experimental and modeling studies of fundamental nonequilibrium discharge processes ***(leader: Alexander Fridman, Drexel).***

Thrust 4. Studies of diffusion and transport of active species in representative two-dimensional reacting flow geometries (*leader: J. William Rich, OSU).*

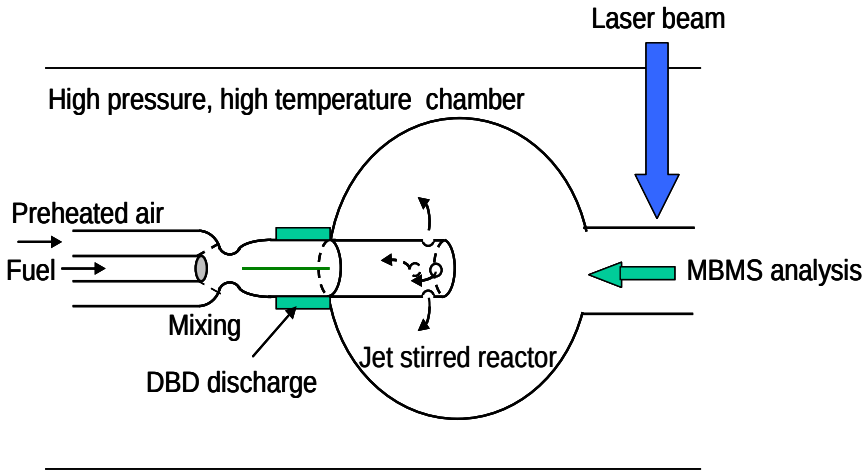
Thrust 1 Overview I:
Low to Moderate (T=300=800K) Temperature Facilities

The Ohio State University — Nonequilibrium Thermodynamics Laboratories

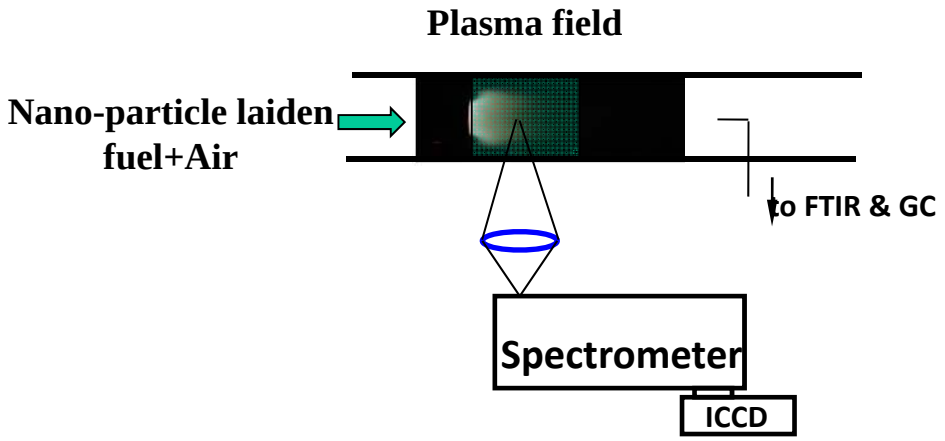
OSU Optical access Furnace (P to ~2-3 Bar) – Extensive Optical Diagnostics (LIF, CRDS, CARS, etc)



Princeton plasma jet stirred reactor (P to ~5 Bar)
Molecular Beam Mass Spectrometer



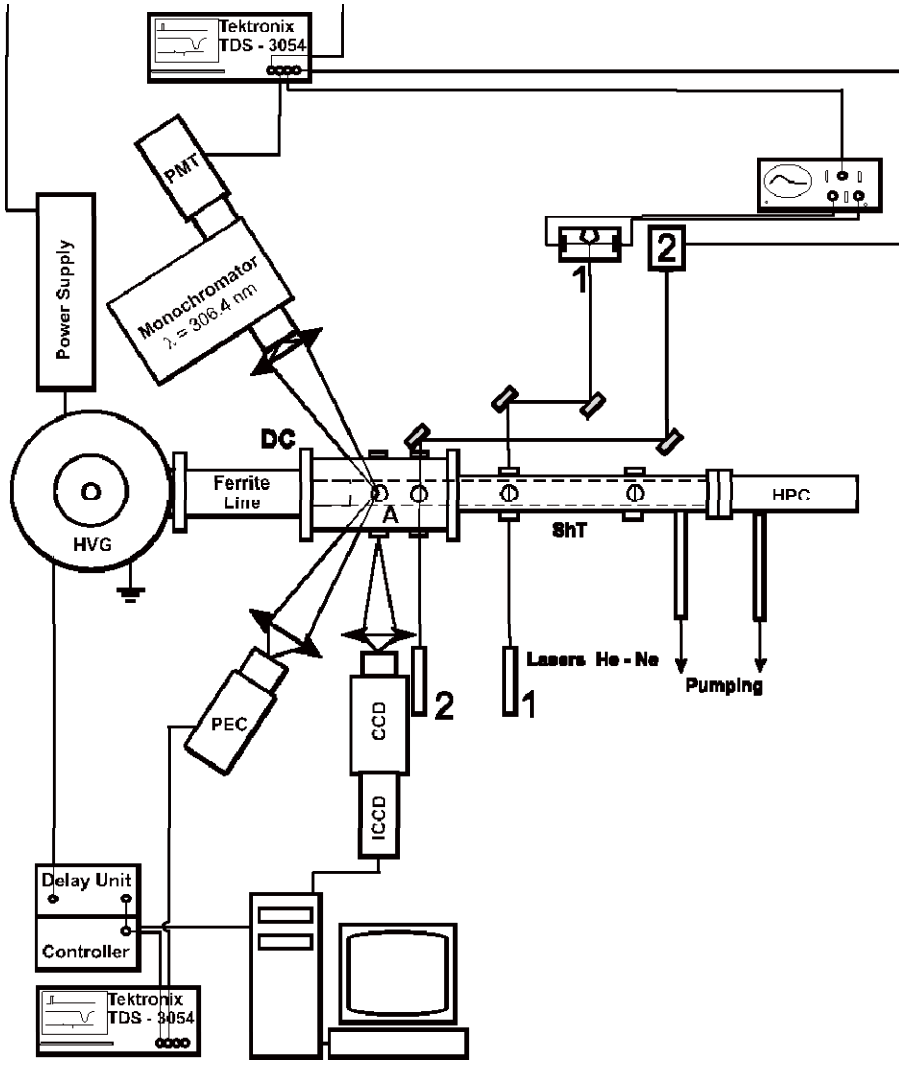
PSU Laminar Flow Reactor
(FTIR , GC – P to 10 Bar)
Nanoparticle Effects



Thrust 1 Overview II:
Moderate-to-high (T=800 – 1800 K) Temperature Facilities

The Ohio State University

Nonequilibrium Thermodynamics Laboratories



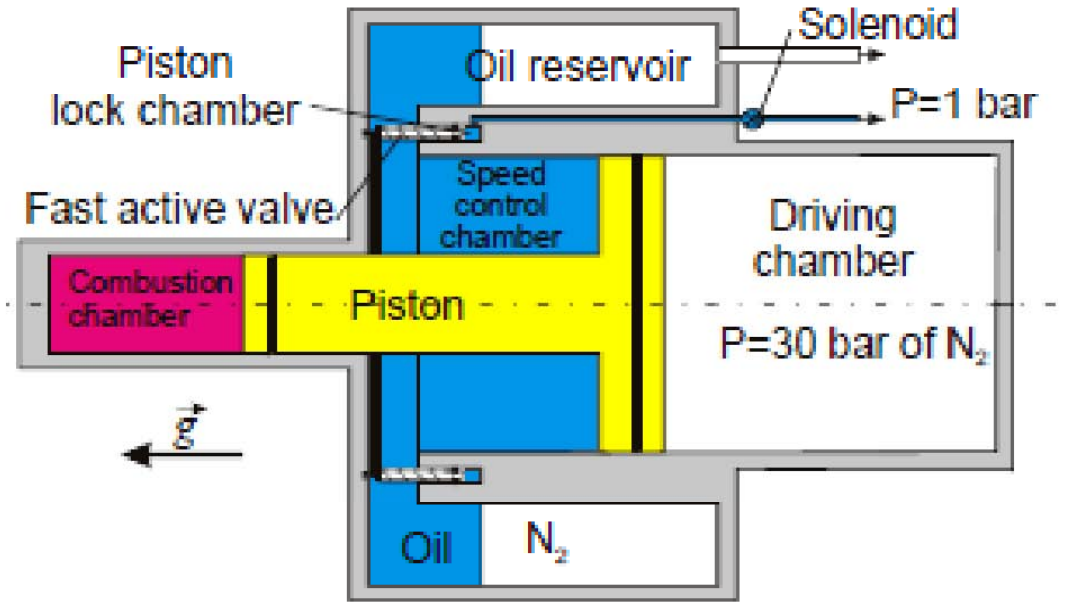
Drexel Discharge Shock Tunnel facility

i. **Shock Pre-Heated Fuel/Air Mixture .**
ii. **Plasma Initiated by FIW.**
iii. **Extensive Diagnostic Suite.**

Thrust 1 Overview III:
Drexel High Pressure (Up to 70 Bar) Facility

Drexel Rapid Compression Machine

Nsec pulser – DC sustained (non-self-sustained) discharge.
Enables wide E/n range.



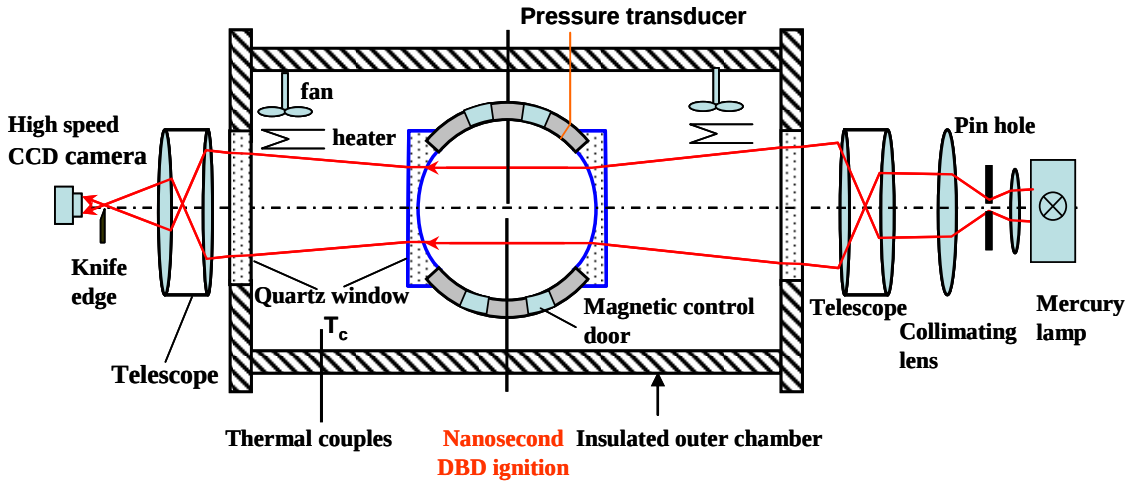
Thrust 1 Overview IV:
Ignition and Flame Speed Enhancement

The Ohio State University

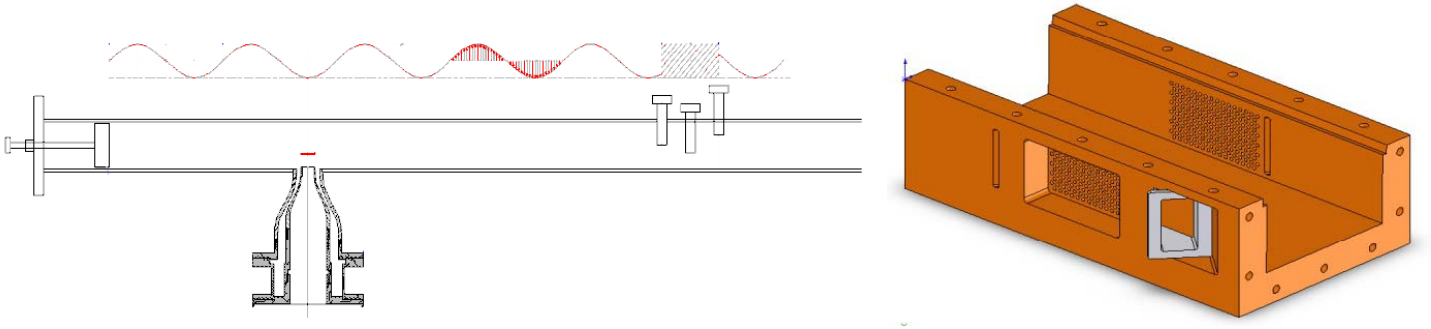
Nonequilibrium Thermodynamics Laboratories

Princeton high pressure combustion chamber

(Transport and volume effects on ignition delay and minimum ignition energy)



Princeton Resonant Microwave Cavity - co-Flow Burner



Thrust 2 Overview

Kinetic model development and validation

- **Development and validation of a predictive kinetic model of non-equilibrium plasma fuel oxidation and ignition, using kinetic data sets generated in Thrust 1.**
  (Task co-Leaders: R. Yetter, Y. Ju, I. Adamovich).

- **Mechanism Reduction and Dynamic Multi-time Scale Modeling of Detailed Plasma-Flame Chemistry.**
  (Task Leader: Y. Ju. Principal Collaborator: V. Yang).

Thrust 3 Overview
Discharge Properties

(i) Key parameter measurements

Electric Field by CARS

Electron Density - Temperature (EEDF?) by Thomson scattering and Radar REMPI

VDF of Major Species by CARS

(ii) Structure of Ionization Waves

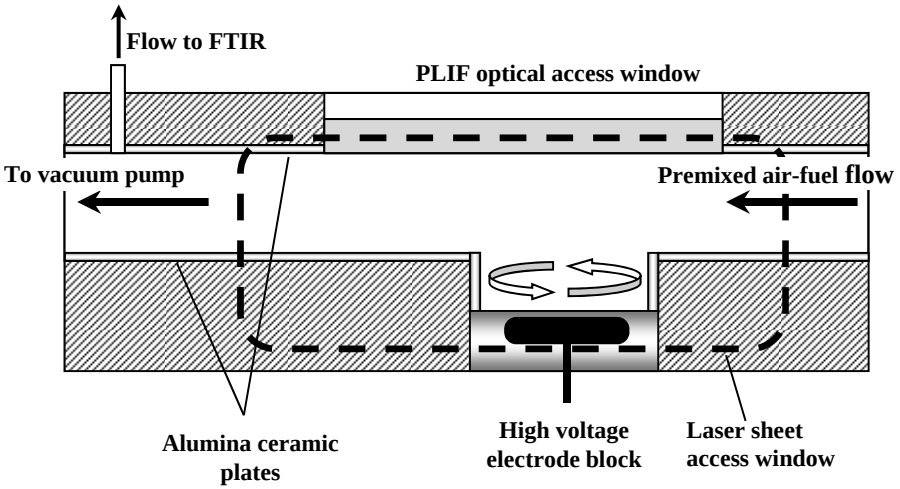
(iii) Electron Impact and Photo Ionization

(iv) Integration with Thrusts 1/2 for nsec pulsed plasma code development / validation.

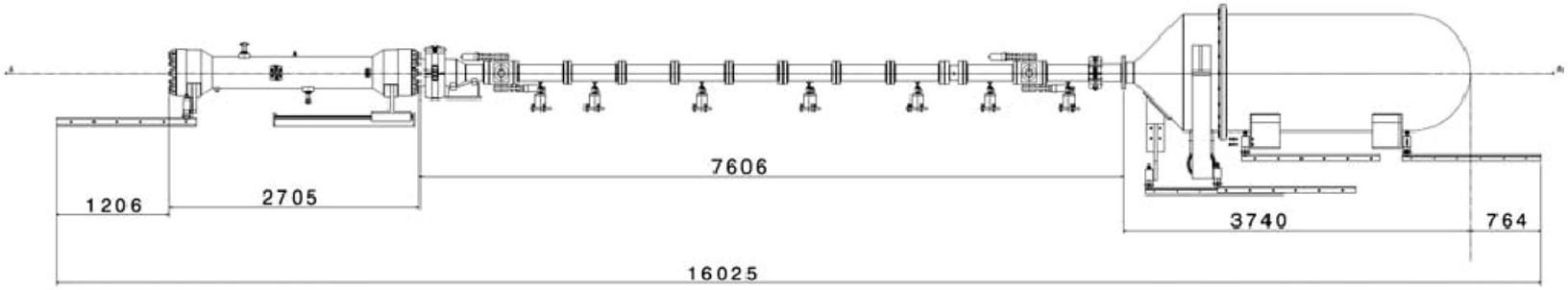
Thrust 4 Overview I:
Ignition / Flame Holding in Cavity and High Speed Flows

The Ohio State University — Nonequilibrium Thermodynamics Laboratories

OSU Plasma cavity flow ignition experiment.



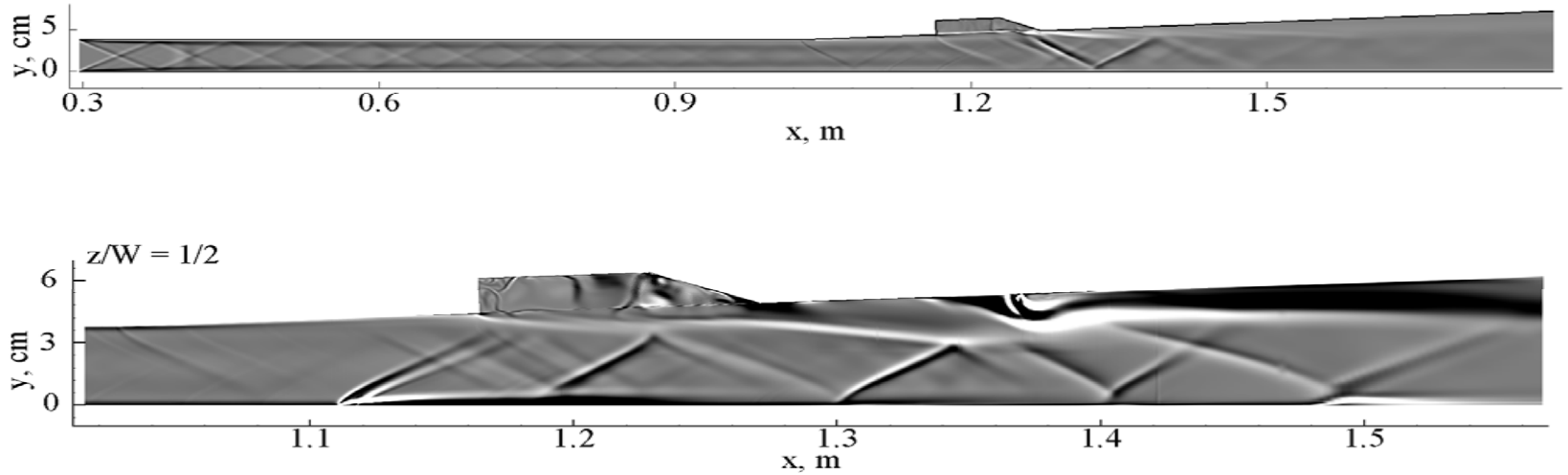
Drexel Shock Tunnel



Thrust 4 Overview II:

High Fidelity Modeling of Complex Environments and Flow Paths

Computational shadowgraph of flowfield in AFRL scramjet combustor test facility.



Role of International Collaborators

- **Direct participation during visits to MURI team member institutions (15K / yr provided in institutional cost share).**
- **Attendance at planned workshops (at AIAA meetings).**
- **Informal consulting (including other meetings attended by MURI team members).**

Thrust 1 (primarily)

Christophe Laux, Svetlana Starikovskaya

Thrust 2 (primarily)

Boris Potapkin, Nickolay Aleksandrov, Aleksander Konnov, Fei Q

Thrust 4 (primarily)

Sergey Leonov

Program Management

- **Periodic (monthly) teleconferences.**
- **Twice Yearly Informal Workshops**

  (in conjunction with Aerospace Sciences and PD&L AIAA meetings).
- **Formation of Government/Industrial Advisory Board.**

Questions / Discussion?